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Analysis of Energy Efficiency of Building Envelopes of JSC "Station EGRES-2"

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Abstract: Improving the energy efficiency of building envelopes can make a huge contribution to the development of industry by reducing the cost of heating and ventilation of buildings. The aim of the work is to identify possible reserves of energy resources savings by detecting defects in structures and the use of building materials that do not meet the climatic conditions of the region and to make proposals for the optimal solution of the problem. Research objectives: conducting an instrumental survey of buildings, analysis of the results of the survey, analysis and calculation of resource savings by insulating the walls of buildings. Modern methods of research of building structures for compliance of their thermal-physical properties with the normative requirements are offered. The estimation of heat protective properties of protecting constructions of buildings on the basis of thermal imaging inspection for revealing the latent defects of constructions and heat isolation is presented. Consumption of energy resources for heating and ventilation of buildings and structures, the existing measures in the field of energy saving and improving the quality of the enclosing structures are considered, and the results of the instrumental inspection of the object are analyzed. The effective way of increasing the energy efficiency of building envelopes - spraying polyurethane foam - is proposed.

INTRODUCTION

Currently, traditional methods of thermal imaging are widely used to assess the thermal properties of building envelopes [1, 2].

Definition of real characteristics of thermal protection of buildings is regulated in a number of normative documents [3, 4], in which the tasks before builders in questions of rational use of thermal energy are defined. According to these normative documents, the energy passport of a building is developed, and thermal imaging of an object is carried out. The energy passport - the regulated normative document in which forms by results of energy audit the actual and recommended indicators of energy efficiency and the program of realization of the available reserve of economy of energy resources are reduced.

The main types of defects detected by infrared thermography are:

- places of air and water leaks (defective grouting of joints on the outside, peeling of the mastic film from the concrete surface, insufficient compression of the sealant and cracks in the mortar and mastic, defects of window units and openings: poor-quality sealing of walls with putty, through gaps in the joints of the bottom elements of boxes, discontinuous mastic in the mouth of the window unit latch joint)
- thermal bridges; deterioration of heat transfer resistance (lack of thermal insulation, abnormal dampness, poor quality brickwork, incorrect architectural and construction solutions, etc.)
- defective panels of building envelopes (violations of the thickness and placement of insulation, adsorption of moisture in the insulation, overestimation of the bulk weight of expanded clay aggregate, settling insulation, chipping of the edge of the panel);
- delamination of plaster, cladding and other coatings [5].

As ways to improve the thermal efficiency of buildings, methods of optimization of heat protection of enclosing

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structures, the search and selection of architectural and planning solutions, the use of modern engineering systems and available alternative energy sources are used.

The optimization of heat protection of enclosures is usually understood as the development of structures with minimal heat consumption for the operation of buildings at minimal cost, but with the condition of simultaneous full preservation of functional requirements. Achieving minimum heat loss is directly related to increasing the thickness of insulation, which increases the overall heat transfer resistance, as well as to improving the moisture conditions of enclosures, improving the design of horizontal and vertical joints, size and area of glazing.

The search and selection of architectural and planning solutions is carried out within the framework of the considered building type taking into account the climatic characteristics of the construction area and the landscape area. As a result, the choice of building orientation, facades with special attention to the direction of the prevailing winds, possible reduction in the area of the outer surface of the building, reducing overall heat loss, the rational layout of interior spaces [6].

The aim of the work is to identify possible reserves of energy resources savings in the detection of defects in the structures of buildings and to make proposals for the optimal solution of the problem. Research objectives: conducting an instrumental survey of buildings, analysis of the results of the survey, analysis and calculation of resource savings by insulating the walls of buildings.

MATERIALS AND METHODS

In order to maintain the temperature in production halls, a long heating season, which includes not only winter, but also a considerable period in spring and autumn, is required to ensure comfortable working conditions for the workers. And in some cases the technology requires temperature control at all times. And in this case, the cost of energy is added to the cost of production. It is much more profitable to insulate the building once. Correctly installed thermal insulation provides:

- reliable thermal protection, enabling economical use not only of heating systems in winter, but also of air conditioning systems in summer;
- saving construction materials when erecting the walls of buildings under construction;
- reducing wall deformation from temperature fluctuations and damage during use [7, 8].

Every production hall has its own special characteristics. Therefore, the insulation must be versatile and practical. Polyurethane foam spraying technology is available for additional insulation. This modern method of thermal insulation should appeal primarily to production workers due to its simplicity. The polyurethane foam consists of two parts: a polyol composition and an isocyanurate hardener. Both components are pressurised by a steam generator and injected into a spray gun, where they are foamed and applied to the surface in an even layer. For better adhesion, it is advisable to apply two coats on the previously prepared area, the first with lower density. Properties of polyurethane are shown in Table 1.

TABLE 1. Physical and technical properties and mechanical properties of polyurethane

The name of indicators	Norm
Density, kg / m^3, not less then	55
Thermal conductivity coefficient, kcal / m • h • ° C, not less then	0.028
Moisture absorption in 24 hours at a relative air humidity of 96%, vol. %, not less then	0.1
Water absorption in 24 hours at saturation with water, vol. %, not less then	2.0
Adhesion strength to metal sheets, kgf / cm^2, not less then:	
with uniform separation	3.0
at shift	2.5
Tensile strength, kgf / cm^2, not less then	3.0
Shear strength, kgf / cm^2, not less then	2.5
Tensile modulus, kgf / cm^2, not less then	100
Shear modulus, kgf / cm^2, not less then	45
Flame retardant additives, wt. %, not less then	5

Sprayed polyurethane foam is the most cost-effective way to insulate industrial buildings, tanks and large diameter pipework. Sprayed polyurethane foam does not require additional installation as it has a high degree of adhesion to all surfaces (excluding oily ones) and the lowest thermal conductivity coefficient saves on the thickness of the insulation layer. In addition, the sprayed polyurethane foam production process creates a seamless insulation that eliminates thermal bridges and moisture penetration to the insulated surface. The polyurethane foam spraying process itself is carried out using special spraying equipment, in which the components are mixed and pressurised with compressed air on the insulated surface. Spraying polyurethane foam is similar to painting with a spray gun [9, 10]. Thickness of layers of different insulation materials, with equal thermal insulation capacity are shown in Table 2.

TABLE 2. Thickness of layers of different insulation materials, with equal thermal insulation capacity

Material	Thickness
Concrete	2132 мм
Brick	942 мм
Wood	340 мм
Mineral wool	125 мм
Styrofoam	75 мм
PPU (polyurethane foam)	30 мм

RESULTS AND DISCUSSION

As a result of thermal imaging inspection of buildings of the JSC "Station EGRES-2" enterprise significant losses of heat energy from the external enclosing structures of the buildings were revealed. Evaluation of quality of execution of thermal protection of envelop structures was carried out on the basis of analysis of thermograms of envelop structures. Objects, on which it is necessary to implement this measure on thermal insulation of external walls of buildings, and their characteristics are presented in Table 3.

TABLE 3. Sites where exterior wall insulation is needed

Buildings	Sst, m^2	R (W/m² °C)	Surface temperature walls, ° C	Inside temperature premises, ° C
Administrative	208.6	1.2	+9.4 ^{0}C to +12.2^{0}C	+22.4 ^{0}C
Turbine branch	450.6	0.8	+3 ^{0}C to +8 ^{0}C	+18 ^{0}C
Diesel fuel warehouse	73.5	0.68	-7 ^{0}C to +8 ^{0}C	+14.2 ^{0}C
Return water station	64.12	0.82	-4 ^{0}C to +2 ^{0}C	+14.8 ^{0}C

According to SP 50.13330.2012 [3], calculated temperature difference Δt °C between temperature of internal surface of enclosing structure shall not exceed rated Δt °C. For external walls for all public, administrative and domestic buildings Δt = 4.5 °C. According to this standard, the building envelope does not meet the requirements of SP 50.13330.2012. The field part of the thermal imaging survey of buildings, structures of JSC "Station EGRES2" was conducted at ambient air temperatures from -32 to -6 °C, both in daytime and in the dark.

More than 2500 images have been taken. Thermograms and photos of characteristic loss locations are presented. A testo 875 - 2i thermal imaging camera was used for the work, with a standard 32 lens as in [11]. The analysis of the results of the field surveys is presented in Fig. 1 to 5.

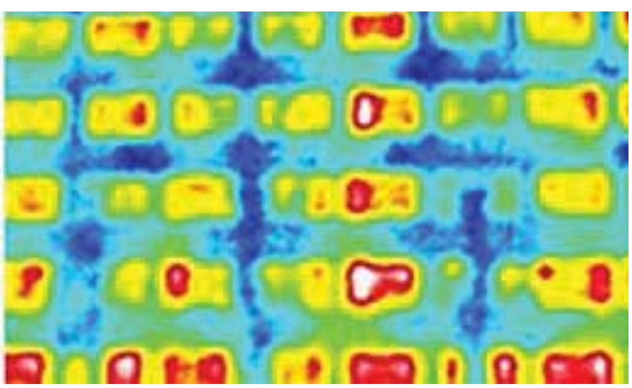


Image options:
Emissivity: 0.93
Reflected temperature, (°C): 20.0

FIGURE 1. Thermogram of the administration building

The thermograms of the administration building clearly show high heat loss through the glazing of the windows, which may be the result of the use of low-quality glazing.

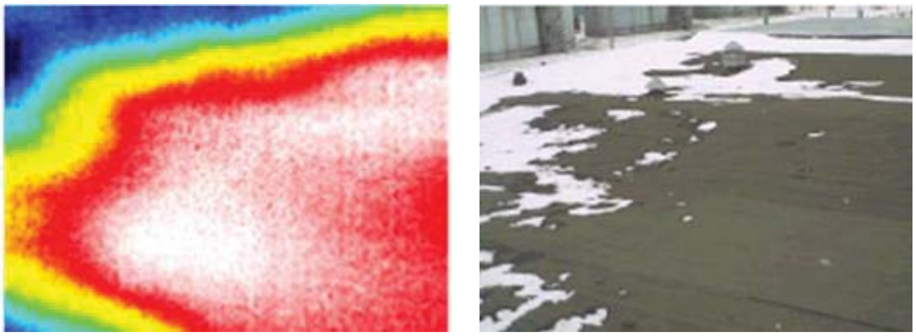
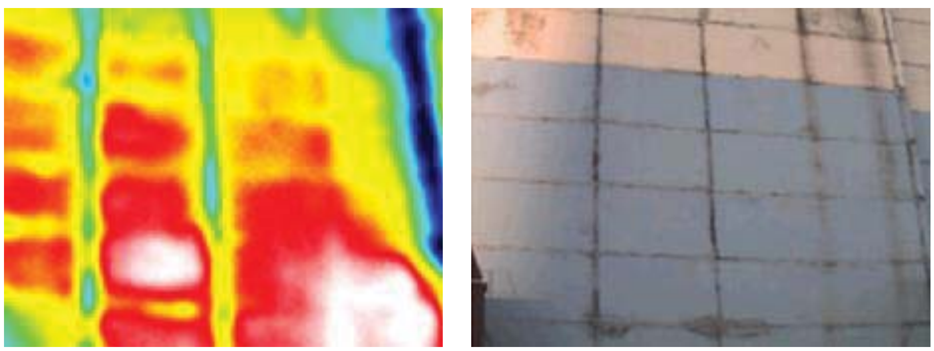


FIGURE 2. Thermogram of the motor vehicle garage roof building

In the thermogram of the roof of the vehicle garage, we see large heat losses over the whole area. This shows that the roof envelope is not fulfilling its function due to the lack of roof thermal insulation or its small thickness, and possibly an incorrectly selected and installed roof thermal insulation material.



Histogram: minimum -20.2;
Maximum 1.1;
Average -4.5

FIGURE 3. Thermogram of the side wall of the crushing building

The thermogram of the side wall of the crushing body clearly shows the presence of large heat losses over the entire area of the enclosing structures, this indicates an incorrect selection of materials for the enclosing structures and, as a result, their failure to fulfill their functional purpose.

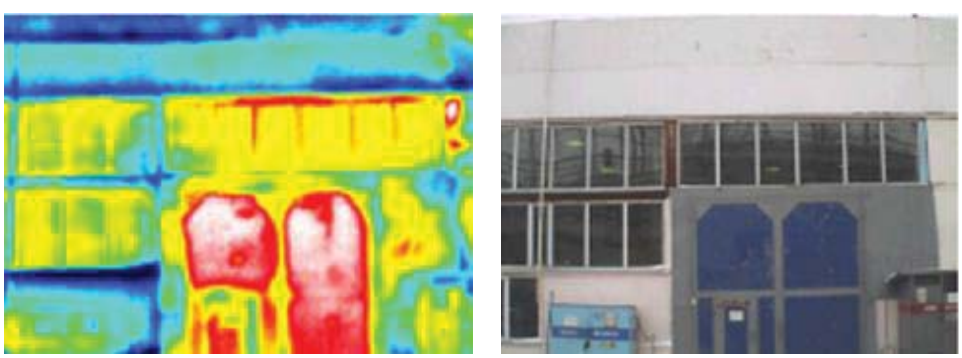


FIGURE 4. Thermogram of the vehicle building

The thermograms of the vehicle building primarily show high heat losses in the structures of window and door openings, joint fillings, high thermal conductivity of wall panels, etc.

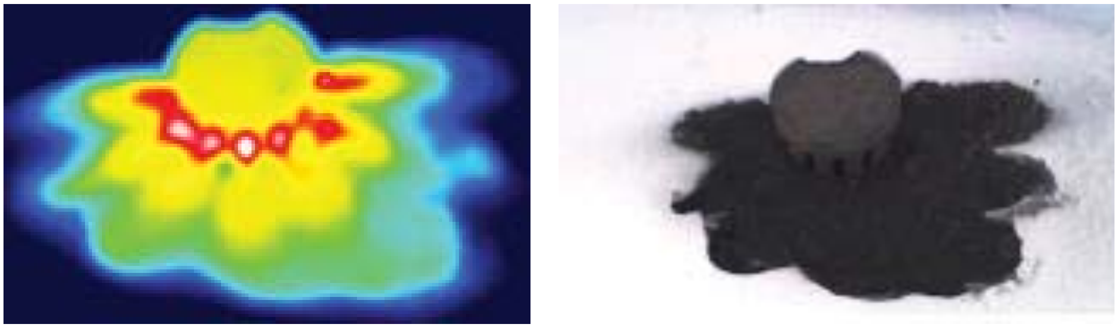


FIGURE 5. Thermal diagram of a car roof with a drainage gutter

The thermogram of the roof of a garage with a gutter shows a high loss of heat energy through the structures of the storm drain and ventilation chambers, as well as over a large area of the roof. This suggests possible breaches of building regulations in the design, construction and operation of the internal storm drainage and ventilation systems as well as a lack of or damage to the thermal insulation in the roof structure of the garage.

The in-situ portion of the thermal imaging surveys identified characteristic areas of significant heat loss:

-glazed surfaces;

-entrance groups;

- Top surfaces of window and door frames and gates;

-surfaces with insufficient or defective thermal insulation;

-Elements of interface of inter-storey ceilings, coverings, external envelopes and partition walls in monolithic reinforced concrete design;

-Elements for heating, ventilation and drainage systems.

The calculation method has been used to estimate the economic benefit to be gained by insulating exterior walls with polyurethane foam. The calculation results for resource savings due to insulation of building walls with polyurethane foam are shown in Table 4. The final saving will be 108.4 Gcal per year, which is 8% of the heat consumption for heating and ventilation.

TABLE 4. Data on resource savings due to thermal insulation of building walls

	Object name	Wall area, m^2	Saving, Gcal per year	Saving, tenge per year
1	Administrative building	208.6	33.14	164 000
2	Mechanical workshops. Warehouse of tools and materials	450.6	58.3	288 300
3	Turbine department	73.5	10.2	50 500
4	Compressor station	64.12	7.1	35 100
	TOTAL	796.82	108.74	538 000

CONCLUSION

The results of this study lead to the following conclusions:

- Poor quality installation and materials that do not meet the technical specifications of the region - signs of over-consumption of heat.
- Thermal imaging inspections can identify thermal energy leaks and poorly installed building envelopes that cannot be detected by visual inspection.
- Insulating the building envelope with modern, low-thermal conductivity materials increases the energy efficiency of the building.
- The payback on the insulation of the building envelope is quite high, due to the significant savings in energy resources.

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